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Geochemical Characteristics of Carbonates in Loess-paleosol Sequences of the Chinese Loess Plateau: Implications for Paleoenvironmental Reconstruction

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The Chinese Loess Plateau (CLP), spanning north-central China, is characterized by thick deposits of wind-blown silt and fragile ecosystems. Renowned as a cradle of ancient Chinese civilization, its unique loess-paleosol sequences and the carbonates within provide invaluable records of Quaternary paleoclimate and environmental changes. However, a comprehensive understanding of carbonate formation, geochemical controls, and diagenesis remains limited.

In this study, the δ13C, δ18O, and trace element/Ca ratios of carbonates were analyzed from bulk samples, clay-sized fractions, nodules, and fossil land snail shells from the Mangshan profile. Fossil snail shell carbonate exhibits partial transformation from aragonite to calcite, while the other all are secondary calcite. Acetic acid-leachable Mg, Al, K, B, Ba, and Na in clay-sized and bulk samples indicate contributions from non-carbonate components, with the highest Al/Ca and B/Ca values observed in clay-sized samples. The Mg/Ca and K/Ca ratios across sample types are partially explained by the distinct partition coefficients of aragonite and calcite. The δ13C of land snail shells range from -6.87‰ to -1.59‰, lower than those of bulk samples (-3.57‰ to -1.51‰), clay-sized fractions (-5.12‰ to -1.27‰), and nodules (-3.46‰ to -1.56‰), suggesting a C3-plant dietary preference for land snails and atmospheric CO2 contributions to inorganic secondary carbonates. The δ18O values of land snail shells (-9.61‰ to -2.83‰) are higher than those of bulk samples (-9.88‰ to -8.77‰), clay-sized fractions (-10.34‰ to -7.61‰), and nodules (-9.92‰ to -9.10‰), reflecting differences in growth seasons, rainfall δ18O variability, and evaporation processes. Notably, Sr/Ca ratios in clay-sized fractions show a significant positive correlation with δ18O, while B/Ca, Na/Ca, and K/Ca ratios in clay-sized fractions and Na/Al ratios in bulk samples exhibit negative correlations with magnetic susceptibility, suggesting their potential as proxies for rainfall in paleoclimate reconstruction. Overall, the geochemistry of carbonate is influenced by mineral formation processes and non-carbonate mineral contributions, highlighting the complexity of interpreting carbonate records in loess-paleosol sequences.